

# Controlled subsurface drainage for Southern Coastal Plains soil

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**ABSTRACT**—A field study of water table control through subsurface conduits on a typical Southern Coastal Plains soil showed that in these sandy soils the water table must be kept at 42 inches or less from the soil surface. Silage yields from a field under controlled drainage were greater than those from a nondrained field. For each additional day, between 25 and 55 days, that the water table was less than 42 inches from the soil surface, silage yields increased 0.3 to 0.6 ton per acre.

UP to 10 inches of rain within a day or two, followed by several days with no rainfall, is a relatively common occurrence in the Southern Coastal Plain. Because the area's sandy soils have a water-holding capacity of only about 1 inch per foot of soil, they often do not hold enough water to supply crop needs even during short drought periods. But if the water table is maintained close enough to the soil surface, roots can withdraw water from the capillary fringe area above the water table and reduce plant water stress.

We conducted a field trial to study controlled subsurface drainage on a typical Coastal Plains soil in South Carolina. Our objectives: to manage excess water to maintain and enhance crop production and to keep the water table close enough to the soil surface to provide water for crops during periods of little or no rainfall.

## Scope of Problem

### Drainage in the Southern Coastal

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Plain dates back to colonial days (8). Early drainage systems consisted of small open ditches to drain wet spots. Most drainage systems today are designed to remove all "free" water from the soil profile to the approximate depth of the outlet ditch.

In recent years, scientists and engineers have become concerned about overdrainage, particularly in sandy soils. Yields of soybeans grown in Carolina bays were higher where surface drainage removed only 0.7 inch of water per year than in bays where tile drainage removed 3.5 inches of water (2). Ward (6) described the extensive drainage needed in the Florida Everglades for flood control and the resulting effects of drought on the land, wildlife, and towns.

The Soil Conservation Service (SCS) engineered a drainage system—parallel ditches spaced 300 to 500 feet apart on 400 acres of cropland—for the Spring Island Plantation, an island off the South Carolina coast near Beaufort. After the system was installed, crops could not be grown because of extreme drought.

After control structures were added and the water table was raised to within 3 feet of the soil surface, adequate water was available to produce more than 100 bushels of corn per acre.

SCS estimates that in South Carolina alone over 1.5 million acres of sandy or loamy soils have a seasonally high water table on which controlled drainage could be used. The Coastal Plains of North Carolina and Georgia also contain extensive farm acreages where controlled subsurface drainage

is applicable. Skaggs, Kriz, and Bernal (4) estimated the North Carolina acreage at 1.5 million.

Williamson and Kriz (7) reported that corn yields peaked when the water table in lysimeters was controlled about 30 inches below the soil surface.

## Controlled Subsurface Drainage

Ordinarily, subsurface drainage with buried conduits lowers the water table to the approximate level of the conduits. But with controlled subsurface drainage, the water table recedes to a level above the conduits, which is "controlled" by an elevated outlet. Only water that may hinder root development and growth is permitted to drain from the soil. However, the water table fluctuates between underground conduits (Figure 1). After a rain, when the system is in the drainage cycle, the water level is higher between conduits than near the conduit. When drainage ceases and the system is in the drying cycle, water flows from the conduit to the center, and the water level is lower between conduits than near the conduit. Water table variations between conduits are affected by the conduit spacing, soil hydraulic characteristic, and evaporation rates and plant water uptake. Several researchers have explained the theory relating water table control to subsurface conduit spacing and depth (3, 4).

Advantages of controlled drainage over free outfall drainage include the following:

1. Water can be held in the soil and outlet ditch and supplied to the crop through the existing drainage system without modifying that system, except to add an outlet control structure.
2. Labor and maintenance costs are low.
3. The subsurface conduit system is

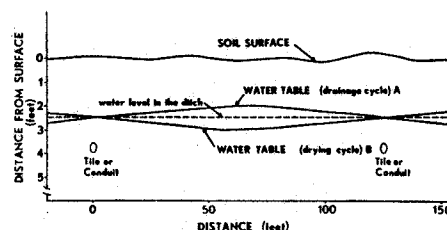


Figure 1. Depth to the water table between tile lines during drainage and drying cycles.

used for both drainage and subirrigation.

4. The water table can be regulated to suit varying conditions and weather patterns.

There are three primary disadvantages of controlled drainage:

1. The initial cost of a new system, if installed on land requiring extensive grading to insure uniform distribution of water in the soil profile, is high.

2. During heavy or extended rainfall, with the water table held near the surface, fields may become muddy, creating unsatisfactory working conditions.

3. Crop management practices for a high water table are not well known.

### Installation and Procedures

Our field trial was established on a 60-acre field near Ridgeland, South Carolina (Figure 2).<sup>1</sup> The field was divided by a drainage ditch into approximately equal sections. One was controlled drained through underground conduits. The other was not drained. We placed a flashboard riser at a predetermined elevation on the 36-inch road culvert at the lower end of the outlet ditch to control the water flowing from the field and the water level in the ditch. Water level recorders were placed on 5-inch observation wells at the locations shown in figure 2. Rainfall was measured with a recording raingage.

During the 2-year study, the controlled-drained and nondrained fields were planted to corn, which was harvested for silage. Silage yields were measured in 1973 near each observation well. Dry matter production and the fresh weight of corn ears in the husk were determined from samples taken at the same locations.

### Soil Description

The soils in the field trial area are Ocilla and Seewee loamy fine sands. Disturbed soil samples were taken at various depths when the observation wells were dug. The SCS laboratory in Fort Worth, Texas, determined particle size distribution (Table 1).

The apparent hydraulic conductivity, determined from conduit outflow,

<sup>1</sup>We thank Hancor, Inc., Mebane, North Carolina, and Advanced Drainage of North Carolina, Inc., Roland, for furnishing the corrugated plastic drain tubing for the numbered conduit lines.

water-table drawdown, and a theoretical drainage equation (5), ranged from 93 to 127 feet per day. We used the average of 111 feet per day in all calculations.

### Perimeter Losses

An estimate of lateral losses from the field perimeter is necessary to determine if controlled drainage will be satisfactory. This should be made when the water table is high.

We determined the slope of the water table, considered the hydraulic gradient, away from the field on the south and east by measuring the water table elevation in the field and 500 and 1,000 feet away from the field. Using the Darcy equation of continuity, we calculated perimeter losses from the controlled drainage field, assuming no losses from the ditch, of 17,760 cubic feet per day or 0.11 inch per day from the experimental area. This loss was less than half the maximum daily evapotranspiration losses.

### Results and Discussion

#### Water Table Control

Controlled drainage effectively kept the water table at a level so that plant roots could extract water from the fringe area above the water table. For example, from April 18 to July 18, 1973, the water table in the controlled-drainage field remained at a depth of less than 42 inches for about 20 days more than in the nondrained field. In addition, the water table in the controlled-drained field dropped to a depth greater than 30 inches 3 to 10 days sooner after large rains than in the nondrained field.

Figure 3 shows the water level in the ditch, the water table elevations

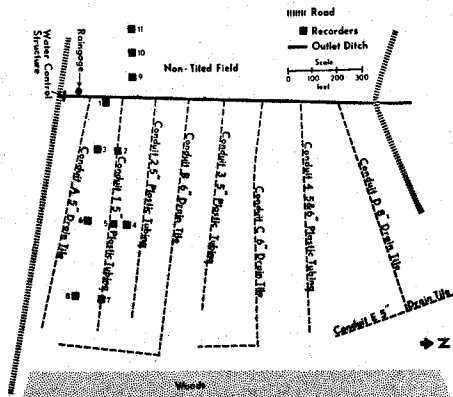


Figure 2. Field layout of controlled-drainage trial.

by conduit 1 at 226, 529, and 832 feet from the ditch during the growing season, and daily rainfall. The top flashboard, set at an elevation of 52.3 feet above mean sea level, kept the water level in the ditch near this elevation, except for short periods after rainfall and during low rainfall periods. Distance from the ditch made little difference in the water table elevation in the controlled-drainage field. The water table in the field was less than 1 foot below the elevation of the water in the ditch and fluctuated with the water level in the ditch. For example, low rainfall from June 1 to June 19, 1972, caused the water level in the ditch to recede to its lowest point. The drop in the water table at all measuring stations closely paralleled the changes in the ditch water level. More than 5 inches of rain fell between June 19 and June 21 during Hurricane Agnes. The water table rose rapidly, but did not get closer than 2 feet to the surface. Within 3 days it dropped to 2.5 feet

Table 1. Particle size distribution, expressed as percent finer by weight, for the nontiled and controlled-drained fields.

Particle Size Distribution <sup>a</sup>						
Field	Depth of Sample (ft)	Sand				Unified Classification
		Clay	Silt	Fine	Med.	
Nontiled	0-2	12	6	81	1	SM
	4-5	12	6	81	1	SM
	8	16	3	80	1	SM
Controlled drainage	0-2	6	4	88	2	SP-SM
	2-4	13	8	77	2	SM
	4-5	12	3	84	1	SM
	5	12	5	82	1	SM
	6	14	3	82	1	SM

<sup>a</sup>From data provided by Soil Conservation Service Laboratory, Fort Worth, Texas.

below the soil surface—the 52.3-foot elevation.

Rainfall during the growing season in 1973 was less than in 1972. This permitted evaluation of water table control during an extended drying cycle. Only 1.2 inches of rain fell from April 26 to June 6 in five showers, which was insufficient to maintain water in the ditch. The water level in the ditch dropped to the 50.2-foot elevation during this period (Figure 4), 2.4 feet below the flashboard elevation. During this extended drying cycle, the water table dropped below the conduit at distances of 529 and 832 feet from the ditch. However, the water table in the field varied with the level in the outlet ditch throughout the rest of the growing season at all measuring stations.

### Yield Comparisons

The controlled-drainage field out-yielded the nondrained field by 3.9 tons per acre for silage (20.9 vs. 17.0) and 0.8 ton per acre for fresh corn ears with husks (8.9 vs. 8.1). Silage yields from the controlled-drainage field were statistically greater than silage yields from the nondrained field.

A regression analysis of the data showed that the number of days the water table was less than 42 inches from the soil surface was a factor in the yields produced (Figure 5). A second-order regression equation was selected because yield increases normally vary nonlinearly with water table depth and available soil moisture (7, 9). These data showed that for each additional day between 25 and 55 days that the water table was 42 inches or less from the surface, silage yield increased 0.3 to 0.6 ton per acre.

Fresh corn ear yields were also related to the number of days the water table was controlled at less than the 42-inch depth (Figure 5).

### Conclusions

The Southern Coastal Plains contains millions of acres of sandy soils with low water-holding capacity. Drainage is required to avoid excess water in the soil profile and ponding on the surface during periods of heavy or extended rainfall. However, when the water table is more than 3.5 feet from the surface, roots do not extend far enough to extract water

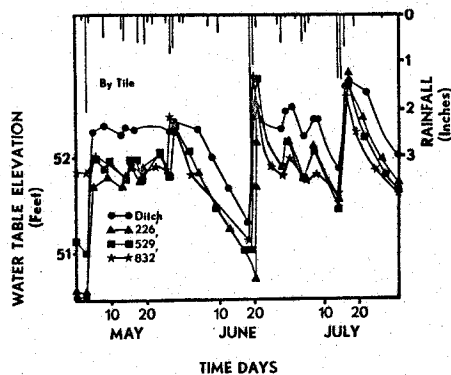


Figure 3. Water table elevations by conduit 1 at various distances from the outlet ditch and rainfall for the 1972 growing season.

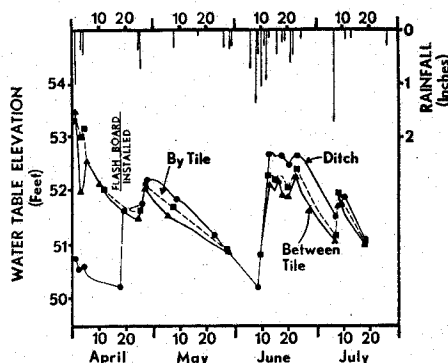


Figure 4. Rainfall and water table elevation in the ditch, by the tile line, and between tile lines 529 feet from the ditch during the 1973 growing season.

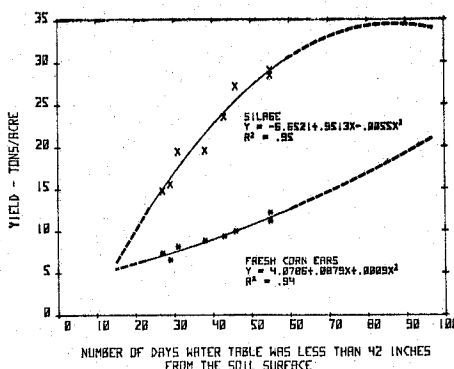


Figure 5. Regression analysis of corn silage yield and of fresh corn ears in the husk versus the number of days the water table was less than 42 inches from the soil surface for the 91-day period prior to harvest.

from the fringe area above the water table, and the soils often do not hold enough water to sustain plant growth until more rain falls.

Controlled drainage—where the water table is lowered to about 3 feet below the surface—shows promise for increasing yields in the Southern

Coastal Plain. Data from our unreplicated 2-year field trial show that the water level in the controlled-drainage field was regulated at distances up to 832 feet from the outlet ditch. Corn silage yield was significantly greater in the controlled-drainage field than in the nondrained field, and yields of corn silage and fresh corn ears in the husk increased with the number of days the water table was less than 42 inches from the surface.

Controlled drainage alone should increase yields in the Southern Coastal Plains, but if the water level in the outlet ditch were controlled by pumping water from a well or lake into it during extended drought, substantial increases in yields might be possible. For example, estimates of silage yields [calculated from De Wit (1)] that can be produced with the sunshine energy available at this location, without other limitations, is about 40 tons per acre. The highest yield in our study was 29.1 tons per acre. If water had been supplied by pumping into the ditch and if the water table in the field had been maintained at less than 42 inches from the surface for the last 3 months of the growing season, the estimated average yield of silage may have increased significantly, as projected from the nonlinear regression equation.

### REFERENCES CITED

- De Wit, C. T. 1965. *Photosynthesis of leaf canopies*. Agr. Res. Rpt. No. 663. Inst. Biol. and Chem. Res. on Field Crops and Herbage, Wageningen, Netherlands.
- Doty, Coy W. 1973. *Pump drainage in Carolina bays*. J. Irrig. and Drainage Div., ASCE 99 (IR4): 465-475.
- Fox, R. L., J. T. Phelan, and W. D. Criddle. 1956. *Design of subirrigation systems*. Agr. Eng. 37(2): 103-107.
- Skaggs, R. W., G. J. Kriz, and R. Bernal. 1972. *Irrigation through subsurface drains*. J. Irrig. and Drainage Div., ASCE 98 (IR3): 363-373.
- Van Schilfgaarde, Jan. 1963. *Design of tile drainage for falling water tables*. J. Irrig. and Drainage Div., ASCE 89 (IR2): 1-12.
- Ward, Fred. 1972. *The imperiled Everglades*. Natl. Geogr. 141(1): 1-27.
- Williamson, R. E., and G. J. Kriz. 1970. *Response of agricultural crops to flooding, depth of water table and soil gaseous composition*. Trans., ASAE 13(2): 216-220.
- Wooten, Hugh H., and Lewis A. Jones. 1955. *The history of our drainage enterprises*. In *Water, the Yearbook of Agriculture*. U. S. Dept. Agr., Washington, D. C.
- Wu, I-pai, and Tung Laing. 1972. *Optimal irrigation quantity and frequency*. J. Irrig. and Drainage Div., ASCE 98 (IR1): 117-133. □